SUITABILITY OF PEANUT RESIDUE AS A NITROGEN SOURCE FOR A RYE COVER CROP

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ABSTRACT: Leguminous winter cover crops have been utilized in conservation systems to partially meet nitrogen (N) requirements of succeeding summer cash crops, but the potential of summer legumes to reduce N requirements of a winter annual grass, used as a cover crop, has not been extensively examined. This study assessed the N contribution of peanut (*Arachis hypogaea* L.) residues to a subsequent rye (*Secale cereale* L.) cover crop grown in a conservation system on a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) at Headland, AL USA during the 2003-2005 growing seasons. Treatments were arranged in a split plot design, with main plots of peanut residue retained or removed from the soil surface, and subplots as N application rates (0, 34, 67 and 101 kg ha^{-1}) applied in the fall. Peanut residue had minimal to no effect on rye biomass yields, N content, carbon (C) /N ratio, or N, P, K, Ca and Zn uptake. Additional N increased rye biomass yield, and N, P, K, Ca, and Zn uptakes. Peanut residue does not contribute significant amounts of N to a rye cover crop grown as part of a conservation system, but retaining peanut residue on the soil surface could protect the soil from erosion early in the fall and winter before a rye cover crop grows sufficiently to protect the typically degraded southeastern USA soils.
Key words: N immobilization, N mineralization, legume, nitrogen fertilizer

RESÍDUOS DA CULTURA DE AMENDOIM COMO FONTE DE NITROGÊNIO PARA UMA CULTURA DE COBERTURA DE CENTEIO

RESUMO: Culturas leguminosas de inverno tem sido utilizadas em sistemas conservacionistas para suprimento parcial das necessidades de nitrogênio (N) de culturas subseqüentes de verão, mas o potencial destas culturas leguminosas de verão no sentido de reduzir as necessidades de N de gramíneas anuais de inverno, utilizadas como culturas de cobertura, ainda não foi extensivamente estudado. Este trabalho avaliou a contribuição dos resíduos de uma cultura de amendoim (*Arachis hypogaea* L.) sobre as necessidades de N de uma cultura subsequente de centeio (*Secale cereale* L.) como cobertura desenvolvida dentro de um sistema conservacionista, em um solo limo-arenoso Dotham (limoso fino, caulinítico, Plinthic Kandiudults térmico) de Headland, AL EEUU, durante 2003-2005. Os tratamentos foram arranjados de acordo com um esquema split-plot, com parcelas principais de resíduos de amendoim retido ou retirado da superfície do solo e, parcelas secundárias de taxas de aplicação de N (0, 34, 67 e 101 kg ha^{-1}) aplicadas no outono. O resíduo de amendoim teve efeito mínimo ou nenhum sobre a produtividade de matéria seca do resíduo, conteúdo de N, relação carbono (C)/N, ou absorção de N, P, K, Ca e Zn. O N adicional aumentou a produção de biomassa do centeio e as absorções de N, P, K, Ca e Zn. Os resíduos de amendoim não contribuem com quantidades significativas de N para a cultura de cobertura de centeio desenvolvida como parte do sistema conservacionista, mas a retenção dos resíduos na superfície podem proteger o solo da erosão no início do outono e inverno, antes que a cultura de cobertura de centeio pudesse proteger os solos tipicamente degradados do sudoeste dos EEUU.
Palavras-chaves: imobilização de N, mineralização de N, leguminosa, fertilizante nitrogenado

INTRODUCTION

In the southeastern USA, legume crop residues have been evaluated in conservation tillage systems to improve crop production and enhance soil physical characteristics (Mitchell & Teel, 1977; Touchton et al., 1984; Oyer & Touchton, 1990; Reeves et al., 1993; Torbert & Reeves, 1996). Typically, legumes are planted after harvest in the fall, terminated in the spring, and a summer crop is planted into that residue.

A major benefit usually associated with legumes is the potential reduction in nitrogen (N) fertilizer expenses for subsequent cash crops.

Legume N in symbiosis with *Rhizobium* bacteria contributes to succeeding non-legume crops upon decomposition of legume top and root material (Bruulsema & Christie, 1987; Touchton et al., 1984). Winter annual legumes, such as crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth.), are utilized as N sources for summer crops (Touchton et al., 1984; Brown et al., 1985; Reeves, 1994). Sunn hemp, a summer legume, has also been shown to decrease corn N requirements in the southern USA (Balkcom & Reeves, 2005). In addition, summer cash legumes have also been examined as an N source for subsequent crops. Researchers in the U.S. Corn Belt have found that alfalfa (*Medicago sativa* L.) and soybean [*Glycine max* (L.) Merr.], can decrease the fertilizer N requirements of a succeeding corn (*Zea mays* L.) crop (Bruulsema & Christie, 1987; Bundy et al., 1993; Morris et al., 1993). Although peanut is a legume that is widely grown in the southeastern USA, no previous research has examined the N contribution of peanut residues to a rye cover crop utilized in a conservation system. Therefore, our objective was to compare the N response and subsequent uptake of selected nutrients for rye grown in a conservation tillage system following removal or retention of peanut residue across four N rates.

MATERIAL AND METHODS

In October 2002, an experiment was established in Headland, AL, USA (85°19’15" W, 31°21’38" N) on a Dothan sandy loam. The experimental area was rotated to a different location each year to utilize peanut residue from the previous peanut crop, but the experiment remained on a Dothan sandy loam. Treatments were arranged with a split-plot structure in a randomized complete block design (n = 4). Main plots consisted of either retention or removal of peanut residues from the soil surface following mechanical harvest of peanut pods. Peanut residue was removed by mechanically raking into windrows and baling the peanut residue. The average peanut biomass was estimated by weighing the baled residue. A subsample of the residue was dried at 55°C for 72 h and ground to pass a 2-mm screen with a Wiley mill (Thomas Scientific, Swedesboro, NJ)[1] then further ground to pass a 1-mm screen with a Cyclone grinder (Thomas Scientific, Swedesboro, NJ)[1]. The peanut residue was analyzed for total C and N by dry combustion in a LECO CN-2000 analyzer (Leco Corp., St. Joseph, MI)[1]. An additional 0.5 g subsample was digested in a 70:30 mixture of nitric and perchloric acid overnight (Hue & Evans, 1986) and analyzed for total P, K, Ca, and Zn using an inductively coupled argon plasma spectrophotometer (Jarrel-Ash Division/Fisher Scientific Co., Waltham, MA)[1]. A rye cover crop was drilled at 101 kg ha^{-1} across the experimental area on 20 November 2002, 30 October 2003, and 15 November 2004. Subplot treatments were N rates (0, 34, 67, and 101 kg N ha^{-1}) broadcast-applied in the fall, as NH_4NO_3, to the cover crop. Nitrogen was applied to the rye cover crop on 21 November 2002, 14 November 2003, and 3 December 2004. Plot dimensions were 7.3 m wide and 12.2 m long.

Rye biomass production was measured the following spring, prior to termination, on 23 April 2003, 8 April 2004, and 11 April 2005 by cutting all the aboveground biomass at the soil surface randomly within each plot on a 0.25 m^2 area. Samples were dried at 55°C for 72 h and weighed to determine total biomass production. A subsample of the dried rye biomass from each plot was ground, and analyzed for total C, N, P, K, Ca, and Zn using the procedures described above. Total biomass of the rye multiplied by the concentration of selected nutrients was used to determine the uptake of individual nutrients. All response variables were analyzed using the MIXED procedure (Littell et al., 1996) and the LSMEANS PDIFF option to distinguish between treatment means (release 9.1; SAS Institute Inc.; Cary, NC). Data were analyzed in relation to year, peanut residue, N rate, and their interactions as fixed effects in the model, while replication, replication × peanut residue, replication × nitrogen, and replication × year were considered random. Single degree-of-freedom contrasts were used to evaluate linear and quadratic effects of N rates for each response variable. If a single degree-of-freedom contrast indicated a significant linear or quadratic response, the specified regression model was fit with the PROC REG procedure (SAS Institute, 2004). Treatment differences were considered significant if $P \leq 0.10$ *a priori.*

RESULTS AND DISCUSSION

Peanut residue biomass and selected nutrient concentrations are shown in Table 1. Variability in nutrient concentrations existed among years, however in 2005 the K concentration was 72% lower than the concentrations observed during 2003 and 2004. The N

[1]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA or Auburn University and does not imply approval of a product to the exclusion of others that may be suitable.

Table 1 - Dry matter peanut residue yield, C/N ratio, concentration, and mass basis of selected nutrients (C, N, P, K, Ca, and Zn) measured after peanut harvest at the Wiregrass Research and Extension Center in Headland, AL USA from 2002-2004.

Peanut residue variable	Peanut crop year		
	2002	2003	2004
Peanut residue yield, kg ha^{-1}	3160	3230	3360
C/N ratio	23.0 (1.3)	35.5 (5.4)	23.1 (1.7)
	Concentration		
	g kg^{-1}		
Total C	385 (6)	395 (5)	319 (13)
Total N	15 (0.8)	10 (2)	12 (0.4)
Total P	0.9 (0.06)	1.4 (0.2)	1.5 (0.01)
Total K	11 (1.5)	12 (1.0)	3.1 (0.02)
Total Ca	7.6 (0.8)	10.5 (1.0)	8.5 (0.8)
Total Zn	0.01 (0.003)	0.02 (0.005)	0.02 (0.002)
	Mass basis		
	kg ha^{-1}		
Total C	1216 (18)	1247 (16)	1007 (41)
Total N	48 (2)	32 (5)	38 (1)
Total P	3.0 (0.2)	4.6 (0.6)	4.9 (0.04)
Total K	33 (4.2)	37 (4.3)	10 (0.05)
Total Ca	24 (2.5)	33 (5)	27 (2.6)
Total Zn	0.05 (0.009)	0.07 (0.02)	0.07 (0.01)

[1]Numbers in parentheses represent standard deviations n=4. [2]Concentrations are reported on an ash-free basis.

concentration was 14 g kg^{-1} across all three years of the experiment. This N concentration was comparable to that reported by Balkcom et al. (2004) for post-harvest peanut residue. Based on the average residue production and N concentration, the peanut residue had a total N accumulation of nearly 46 kg ha^{-1}. This amount represents approximately 50% of the recommended N rate for small grain production in Alabama (Mask et al., 1987). However, the amount required for rye utilized as a cover crop would be less than the amount for rye to maximize grain production. This measured amount of N could increase rye biomass production and enhance benefits associated with winter cover crops, such as controlling erosion, improving infiltration, and increasing organic C inputs (Reeves, 1994).

Since much of this peanut residue N is present in the organic form, not all the N would be immediately available for plant uptake by the following rye cover crop. Decomposition of the residue by soil microbes is required and what portion of the N the microbes do not use during the decomposition process will be potentially available for plant uptake and/or N loss pathways (e.g. leaching). Despite the peanut residue containing significant amounts of N, P, K, and Ca, peanut residue only influenced rye biomass yields, Ca uptake and to a much lesser degree the N concentration of the rye cover crop (Table 2). These effects were dependent on the year and N level as indicated by the observed three way interactions.

Biomass levels were different among years within a given N rate, regardless of whether or not they followed peanut residue (Figure 1). Biomass levels also differed across different N rates within years when peanut residue was retained or removed. Although the three-way interactions were significant, Figure 1 illustrates that peanut residue had little effect on rye biomass yield compared to the particular growing season and N level applied. This finding was similar for N concentration and Ca uptake.

Interactions were also observed among certain variables between years and peanut residue (Table 2). The interaction observed for N concentration resulted from an inconsistent N concentration in rye observed across years. During the first two years, the N concentration following peanut residue was lower as compared to removed peanut residue, but was higher the last year of the study (data not shown). The lower N concentration observed following retained peanut residue indicates that the peanut residue could have immobilized N, which is supported by the incubation study conducted by Balkcom et al. (2004). However, during the 2005 growing season, N

Table 2 - Analysis of variance probabilities following the removal and retention of peanut residues on the soil surface, subsequent N rates, and the interaction between these effects on rye biomass yield, N concentration, N uptake, C/N ratio, P uptake, K uptake and Ca uptake at the Wiregrass Research and Extension Center in Headland, AL USA from 2003-2005.

Source	df	Rye biomass yield	N concentration	Nuptake	C/Nratio	P uptake	K uptake	Ca uptake	Zn uptake
		--				P > F			--
Year	2	0.0015	0.0123	0.0073	0.0057	0.0009	0.0005	0.0619	0.0000
Residue	1	0.8264	0.7970	0.9110	0.8894	0.8544	0.5527	0.8669	0.4996
Year*Residue	2	0.4794	0.0210	0.1125	0.0625	0.6643	0.2094	0.5265	0.6349
Nitrogen	3	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0002
Year*Nitrogen	6	0.4244	0.6793	0.1154	0.2771	0.2563	0.1033	0.9173	0.0000
Residue*Nitrogen	3	0.7112	0.3214	0.8089	0.4391	0.9411	0.7915	0.8878	0.5273
Year*Residue *Nitrogen	6	0.0412	0.0967	0.4875	0.1219	0.4158	0.1852	0.0197	0.8840

concentration was higher following the retention of peanut residue. Since the N concentration and C/N ratio are related due to the relatively constant C concentration of plant tissues, the interaction for C/N ratio between year and peanut residue was similar to that of N concentration.

The yield potential of the rye appeared to increase each year of the experiment, although the experiment did not remain in the same location each year (Figure 1). Additional N generally increased rye biomass levels, and although the response was not consistent across years or peanut residue levels, additional N above 101 kg ha^{-1} may have increased rye biomass in some cases. However, it is unrealistic to expect growers to apply high rates of an expensive input, like N, to a cover crop, which will not be harvested for grain. On the other hand, as previously mentioned, potential benefits associated with cover crops are enhanced as the management of the cover crops increases. Reiter et al. (2003) reported that cover crop biomass production should be > 4500 kg ha^{-1} for a high residue cereal crop conservation tillage system in Alabama. Based on our results, a minimum of 34 kg N ha^{-1} is required to attain this level of high residue production for conservation systems (Figure 1). Additional N will increase biomass production, but the cost of this N must be weighed against the anticipated benefits of the high residue. Presently, the benefits, associated with an incremental increase in N rate above a specified minimum biomass level, required for high residue are difficult to quantify.

Other nutrients also responded to additional N applied in the fall (Table 2). The response of additional

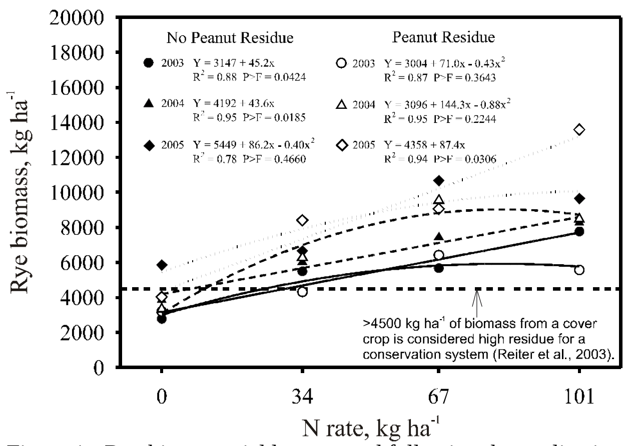

Figure 1- Rye biomass yields measured following the application of four fertilizer N rates to plots with and without peanut residue retained on the soil surface during the 2003-2005 growing seasons at the Wiregrass Research and Extension Center in Headland, AL USA.

N was also linear for other nutrients, except K uptake during the 2004 growing season (Table 3). The reason for increased response of rye biomass and N uptake to additional N would be expected since most crops respond positively to increased N availability. Increases in the uptake of P, K, and Zn are also related. As additional N is applied to rye, growth increased and subsequent uptake of selected nutrients also increased. As a result, P, K, and Zn uptakes increased as N rate increased.

The minimal effect of peanut residue on rye biomass and nutrient uptake may be attributed to the C/N ratio of the residue (Table 1), which has been shown to indicate the likelihood of N mineralization. Low ratios (i.e. < 20 to 1) result in net N mineraliza-

Table 3 - Regression equations for N, P, K, and Zn uptake as a function of fertilizer N rate at the Wiregrass Research and Extension Center in Headland, AL USA from 2003-2005.

Year	Regression equation	R^2	P > F
N uptake			
2003	Y = 25.1 + 0.38x	0.79	0.0033
2004	Y = 17.6 + 0.50x	0.91	0.0003
2005	Y = 33.7 + 0.81x	0.86	0.0008
P uptake			
2003	Y = 7.1 + 0.05x	0.72	0.0075
2004	Y = 5.4 + 0.06x	0.96	<0.0001
2005	Y = 9.7 + 0.11x	0.87	0.0008
K uptake			
2003	Y = 10.6 + 0.10x	0.77	0.0041
2004	Y = 8.2 + 0.20x - 0.001x^2	0.88	0.0050
2005	Y = 16.4 + 0.22x	0.80	0.0027
Zn uptake			
2003	Y = 53.0 + 0.74x	0.90	0.0003
2004	Y = 58.5 + 0.98x	0.93	0.0001
2005	Y = 77.6 + 1.08x	0.93	0.0001

[1]Nitrogen uptake, P uptake, and K uptake, were measured in kg ha^{-1}, while Zn uptake was measured in g ha^{-1}.

tion, while high ratios (i.e. > 30 to 1) result in net immobilization of N (Tisdale et al., 1993). The limited response to other nutrients present in the peanut residue indicates that these nutrients were also not available to rye in greater quantities compared to rye growing where peanut residue was removed. Also, where peanut residue was removed, peanut roots remained. However, the nutrient contribution of peanut roots to the rye cover crop also appears to be minimal.

Although peanut is a legume, the residue remaining in the field after peanut harvest did not contribute significant amounts of N to a rye cover crop based on biomass yield over a 3-yr period. As a result, N rates applied to cereal cover crops, such as rye, should not be reduced following peanut. As expected, rye did respond positively to additional N applications, but 34 kg N ha^{-1} was adequate to enhance biomass production to the level required to qualify as a high residue system on this sandy Coastal Plain soil. However, southeastern peanut producers should retain peanut residue in the field to protect the highly weathered soil surface of Ultisols from erosion and potentially increase soil organic matter contents, which will improve soil physical and chemical properties.

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